Dear spokesperson,

The Workshop on the Intermediate Neutrino Program (WINP) will be held at Brookhaven National Laboratory on February 4–6, 2015. The workshop organizers request that you fill out the enclosed template for describing your experimental plans by January 12, 2015 at 17:00 EST. These templates will be posted on the public WINP website and are intended to facilitate discussion on the best opportunities for neutrino experiments or R&D that can be accomplished in the intermediate time period (~5–10 years) at reasonable cost. Working group convenors may need input from you on an earlier time scale.

Steve Kettell
For the Organizing Committee

1. Name of Experiment/Project/Collaboration:
   Hyper-Kamiokande
2. Physics Goals
   a. Primary
      Neutrino oscillation with beam
      Proton Decay
      Supernova burst neutrinos
      Atmospheric neutrinos
      Neutrino astrophysics (indirect dark matter, diffuse relic SN neutrinos, solar neutrinos)
   b. Secondary
3. Expected location of the experiment/project:
   Kamioka, Japan
4. Neutrino source:
   Upgraded J-PARC neutrino beam
   Natural neutrino sources (see above)
5. Primary detector technology:
   Water Cherenkov
6. Short description of the detector
   One megaton total mass, 560 kton fiducial mass. The baseline design consists of two cavities, each with 280 kt fiducial mass. The inner detector employs 99,000 20" PMTs for 20% photocoverage. Overburden is 1750 mwe.
7. List key publications and/or archive entries describing the project/experiment.
   http://arxiv.org/pdf/1412.4673.pdf
   http://arxiv.org/pdf/1309.0184.pdf
   http://arxiv.org/pdf/1109.3262.pdf
8. Collaboration
   a. Institution list
      See above publications. No formal collaboration at this time.
   b. Number of present collaborator
      See above publications. No formal collaboration at this time.
   c. Number of collaborators needed.

Not determined.

9. R&D
   a. List the topics that will be investigated and that have been completed

      These are the R&D working groups:

      Cavity and tank – Cavity design is being studied considering alternatives to the two-module design. The containment is expected to be a hybrid lining based on concrete and membranes. The objective of cavity and containment optimization is cost reduction.

      Water – The primary R&D is related to the possible use of gadolinium doping. This is already a major R&D topic for Super-Kamiokande and includes a standalone test detector (EGADS). The baseline design is established by the successful Super-K water system.

      Photosensors – Photosensor R&D includes a new dynode design (box and line) and a hybrid photomultiplier employing an APD. In addition, ADIT/Electron Tubes, an alternative vendor (to Hamamatsu) is developing high-QE 11" PMTs.

      Electronics and DAQ – The baseline electronics is an ADC/TDC system comparable to what is used in Super-K, including a TCP/IP distribution of hits and a software trigger. The main R&D required is to develop in-water enclosures to reduce the size of the cabling system.

      Software – Software for detector modeling (WCSim) is under active development, and provides a framework that is available for other water Cherenkov projects.

      Calibration – Calibration is well-understood from Super-K experience although some new sources are being developed. R&D is required to efficiently calibrate as many as 10 individual compartments of the final detector.

      Accelerator and near detectors – Near detector concepts are described in separate contributions to this workshop.
   b. Which of these are crucial to the experiment.

      (1) The most crucial R&D is to determine the photosensor. They are critical in determining the detector performance and detector cost. They also will have a long lead time to manufacture.

      (2) Designs for containment, photosensor mounting, electronics, et al. for the detector are essential for minimizing cost while maintaining the fiducial mass and photocoverage.
   c. Time line

      R&D will be ongoing from now until 2018 and maybe longer for some topics.
   d. Benefit to future projects

      Cavity design is fairly specific to Hyper-K since it depends on local conditions. Water system R&D is beneficial for gadolinium doping in water detectors. Photosensor and electronics/DAQ R&D is broadly applicable to experiments with large arrays of PMTs. The WCSim software package is already being used by other groups. New calibration sources may be useful for other experiments.
10. Primary physics goal expected results/sensitivity:
    a. For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits
    b. For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma.
    c. For sensitivity plots, show 3-sigma and 5-sigma sensitivities

       (note that for neutrino-less double beta decay experiments that have previously been asked for 90% CL and 5 sigma limits these are OK)

d. List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates.
e. List other experiments that have similar physics goals
f. Synergies with other experiments.
The sensitivities of Hyper-K are extensively documented in the provided references. A summary table is presented here:

TABLE: Physics targets and expected sensitivities of the Hyper-Kamiokande experiment.

Physics Target	Sensitivity	Conditions
Neutrino study w/ J-PARC ν		$7.5\,\mathrm{MW} \times 10^7$ sec
– CP phase precision	$< 19°$	@ $\sin^2 2\theta_{13} = 0.1$, mass hierarchy known
– CPV discovery coverage	76% ($3\,\sigma$), 58% ($5\,\sigma$)	@ $\sin^2 2\theta_{13} = 0.1$, mass hierarchy known
– $\sin^2\theta_{23}$	± 0.015	1σ @ $\sin^2\theta_{23} = 0.5$
Atmospheric neutrino study		10 years observation
– MH determination	$> 3\,\sigma$ CL	@ $\sin^2\theta_{23} > 0.4$
– θ_{23} octant determination	$> 3\,\sigma$ CL	@ $\sin^2\theta_{23} < 0.46$ or $\sin^2\theta_{23} > 0.56$
Nucleon Decay Searches		10 years data
– $p \to e^+ + \pi^0$	1.3×10^{35} yrs (90% CL UL)	
	5.7×10^{34} yrs ($3\,\sigma$ discovery)	
– $p \to \bar{\nu} + K^+$	3.2×10^{34} yrs (90% CL UL)	
	1.2×10^{34} yrs ($3\,\sigma$ discovery)	
Astrophysical neutrino sources		
– ^{8}B ν from Sun	200 ν's / day	7.0 MeV threshold (total energy) w/ osc.
– Supernova burst ν	170,000$\sim$260,000 ν's	@ Galactic center (10 kpc)
	30$\sim$50 ν's	@ M31 (Andromeda galaxy)
– Supernova relic ν	830 ν's / 10 years	
– WIMP annihilation at Sun		5 years observation
(σ_{SD}: WIMP-proton spin	$\sigma_{SD} = 10^{-39}\mathrm{cm}^2$	@ $M_{\mathrm{WIMP}} = 10\,\mathrm{GeV}$, $\chi\chi \to b\bar{b}$ dominant
dependent cross section)	$\sigma_{SD} = 10^{-40}\mathrm{cm}^2$	@ $M_{\mathrm{WIMP}} = 100\,\mathrm{GeV}$, $\chi\chi \to W^+W^-$ dominant

11. Secondary Physics Goal
    a. Expected results/sensitivity
    b. List other experiments that have similar physics goals
12. Experimental requirements
    a. Provide requirements (neutrino source, intensity, running time, location, space,…) for each physics goal
13. Expected Experiment/Project time line
    This is a notional time line assuming budget approval in 2016/2017.
    a. Design and development
    Now - 2017
    b. Construction and Installation
    2018 - 2024
    c. First data
    2025
    d. End of data taking
    The beam experiment is assumed to take 10 years. Searches for supernova burst or proton decay may take 25 years or longer.

e. Final results

   Results will be published over the long life of the detector.

14. Estimated cost range
    a. US contribution to the experiment/project

       $20M - $50M
    b. International contribution to the experiment/project

       $100M - $300M
    c. Operations cost

       Operation cost is still being estimated.
15. The Future
    a. Possible detector upgrades and their motivation.

       It is not determined if Hyper-K would run with gadolinium for enhanced neutron detection. A separate R&D effort is underway that may enable gadolinium doping in Super-Kamiokande.
    b. Potential avenues this project could open up.